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Indian Standard

IS 11563 : 2022

गत्यात्मक संपीडकों के लिए तकनीकी आपूर्ति की अवस्थाऐं

(पहला पुनरीक्षण)

Technical Supply Conditions for Dynamic Compressors

(First Revision)

ICS 23.140

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FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Compressor, Blowers and Exhausters Sectional Committee had been approved by the Mechanical Engineering Division Council.

This Indian Standard was first published in 1986. The first revision has been taken up to keep pace with the latest technological developments and international practices. In this revision following major changes have been made:

a) Clause **2** has been added mentioning the latest version of all the referred standards;

b) Clauses **7.1.3**, **7.1.4**. **9.1.8**, **9.2.2**, **9.3.3**, **9.5.1**, **9.6.3**, **9.12.2**, **9.15.2**, **9.18.1**, **12.3.6** and **14.3.1** have been modified;

c) A new type of seal called dry gas seal has been added as clause **9.15.3** (e); and

d) A new clause **11.3** has been added.

The composition of the Committee responsible for the formulation of this standard is given in Annex D.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

TECHNICAL SUPPLY CONDITIONS FOR DYNAMIC COMPRESSORS

(First Revision)

1 SCOPE

It covers the minimum requirements for the supply of dynamic compressors used for handling air, gas, or gas mixtures. It excludes such machines which are termed as fans and blowers.

2 REFERENCES

The standards mentioned in Annex A contain provisions which through their reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibilities of applying the most recent editions of the standards.

3 ENQUIRY SPECIFICATIONS

It is necessary for the customer to furnish the vendor with a clear technical specification so that a satisfactory offer may be made. Annex B gives all the important information to be given by the customer at the time of enquiry.

If the compressors are to operate in parallel with the existing units, the customer shall provide the vendor with the characteristics of the compressors, which are already in operation.

4 ALTERNATIVE DESIGNS

The vendor shall offer alternative designs if required.

5 CONFLICTING REQUIREMENTS

In case of conflict between this standard and the enquiry or order, the agreement reached between the customer and the vendor shall form a part of the order and this shall govern the supply.

6 TERMINOLOGY

6.1 Terms used in this standard are defined as under (*see* Fig. 1):

a) The normal operating point (B) is the one at which usual operation is foreseen and optimum efficiency is desired. Unless specified otherwise, compressor performance shall be guaranteed at this point.

b) Compressor rated point (D) is determined as:

   1) The highest speed required to meet any operating point specified; and

   2) The rated capacity required by the compressor to meet all operating points. The vendor shall select this point such that the capacity encompasses, to the best, specified operating conditions within the scope of the expected performance curve.

c) Normal speed is the one corresponding to the requirements of the normal operating point.

d) 100 percent speed is the one corresponding to the requirements of the rated point (D). This speed can be equal to or greater than the normal speed for motor-driven, compressors, 100 percent speed shall be equal to gear ratio times (if gearboxes are used) the full load speed of the motor being furnished.

e) Maximum continuous speed is the upper limit of the operating speed of the compressor. Unless stated otherwise, the maximum continuous speed shall be 105 percent of the speed of the compressor rated point (B) for variable speed machines.

f) Trip speed for steam turbine drives shall be approximately 110 percent of the maximum continuous speed.

g) Trip speed for gas turbine drives shall be approximately 105 percent of the maximum continuous speed.

h) Stability is the percentage variation in capacity (referred to as rated capacity) between the rated capacity and the surge point at rated speed.

j) Turndown is the percentage variation in capacity (referred to as rated capacity) between the rated capacity and the surge point at the rated head when the compressor is operated with design suction parameters and gas composition.

k) Maximum casing working pressure is the highest pressure that can exist in the compressor under the most severe operating conditions. It shall be either:

   1) The maximum suction pressure to be encountered plus the maximum differential pressure, that the compressor is capable of

developing while operating under the most severe combination of conditions at trip speed; and

2) The safety valve set pressure specified by the customer.

m) Maximum casing design pressure is the one for which the casing is suitable, irrespective of the actual working conditions.

6.2 Customer's specification shall avoid the term 'design operating point' since this shall be used exclusively by the compressor designer. It may or may not conform to any specified operating point.

7 CONTRACT INFORMATION

7.1 Drawings

7.1.1 The customer shall state in his enquiry and order, the period within which the drawings shall be submitted. The customer and the vendor shall agree upon the list of drawings that shall be submitted for review.

7.1.2 Review of the vendor's drawings shall be made promptly, after receipt by the customer.

7.1.3 The vendor shall furnish an electronic copy of the outline dimensional drawings of the compressor unit. The following information shall be included on the outline drawings, other related drawings and data sheets, as applicable:

a) Customer's order number, item number of the equipment, job number, name of the project and location.

b) Weights of the compressor, driver, gearbox base plate, top casing half and the rotor (for horizontally split compressors) or diaphragm rotor pack (for vertically split casings).

c) All principal dimensions including those required for designing the foundation and piping by the customer, maintenance clearances and maximum loading limits on the flanges (forces and moments) and thermal growth data. This includes any requirements of a straight length of gas inlet piping or for vane straightening.

d) The direction of rotation.

e) Size, type, location, identification and proposed use of each pipe and conduit connection including those which shall be plugged.

f) Auxiliary piping, fittings or equipment furnished by the vendor.

g) Make, size and type of couplings.

h) Complete list of reference drawings including those for the driver, lube-oil system, sealing system, controls and the control panel (if any).

7.1.4 Assembly drawings including general arrangement drawings and cross-sectional drawings of the compressor and all the auxiliaries such as oil pumps, relief valves, couplings, seals, etc shall be provided.

7.1.5 The vendor shall furnish a list of relevant fits, clearances and balancing data required for maintenance, repair and assembly.

7.2 Instruction Manuals and Other Data

7.2.1 The vendor shall furnish instruction manuals describing installation, operation and maintenance procedures not later than the date of shipment of equipment. The instruction manuals shall include drivers, auxiliaries and instruments furnished by the vendor.

The instruction manual shall:

a) be organized and indexed by principal equipment items and systems.

b) include written instructions covering start-up, normal shut-down, emergency shut-down, operating limits and routine operational procedures.

c) include the written sequence of installation and final tests and checks for the equipment furnished by the vendor (reference may also be made to the installation and testing details covered elsewhere in this standard).

d) describe constructional features of the compressors and the function of the component parts or system.

e) include an outline and sectional drawings, schematics and illustrative sketches in adequate detail to identify all parts and special equipment and clearly show the operation of all equipment and components and the methods of inspection and repair.

f) include instructions for erecting, piping, aligning and preparing the compressor and its auxiliary equipment for use.

g) describe the rigging procedures and the methods of disassembly, repair, adjustment, inspection and reassembly of the compressor and its auxiliaries.

h) furnish completed, 'as built' data sheets and performance curves.

7.2.2 The vendor shall submit a supplementary offer for spare parts, including all auxiliaries, other than those mentioned in **8.1.2**. The offer shall include recommended spare parts, illustrative sectional drawings reference numbers, price and delivery. Reference number shall identify each part for interchangeable purposes without the need to refer to the serial number of the compressor. Commercially available and bought out items shall be identified by the original manufacturer's reference

numbers. This supplementary offer shall be forwarded to the customer promptly after the receipt of approved drawings from the sub-vendors and in time to permit ordering and delivery of parts prior to start up at the site.

7.2.3 After the receipt of the order, the vendor shall furnish the polytropic head and polytropic efficiency versus capacity curve for each stage and an overall curve for the compressor. After completing the inspection and tests, the vendor shall furnish for each compressor the required copy of performance curves (as designed, for compressors that were not given a performance test at the shop), and the vendor's mechanical run test report. The actual diameter of impellers supplied and the surge curve shall be shown on the performance curves. All curves and data sheets shall bear the serial number of the compressor.

7.2.4 Wherever the compressor vendor furnishes the driver, complete data regarding the driver, including 'as built' datasheets, shall be furnished.

7.2.5 For motor-driven compressors, the vendor shall forward the data as given below:

a) Efficiency and power factor at 50, 75 and 300 percent ratings.
b) Locked rotor current and full load current.
c) Speed versus torque characteristics for the compressor, and motor at rated voltage and specified reduced voltage. The curve shall mention separately the inertia GD^2 of the motor along with the resultant GD^2 of the driven equipment (resolved to the motor shaft) and the calculated time for acceleration to full speed at the specified voltage.
d) Permissible locked rotor time in seconds.
e) Permissible number of consecutive starts when the motor is cold and hot.

7.2.6 The vendor shall furnish the lateral critical speed maps and torsional analysis reports within the period agreed with the customers. The lateral critical speed analysis shall be based on the actual stiffness of the rotor-bearing system.

7.2.7 The vendor shall furnish a report on the noise level measurements when specified.

8 OFFER PROPOSALS

8.1 General

8.1.1 The offer shall furnish complete descriptive information of the equipment the vendor proposes to supply, including necessary drawings, diagrams and data. The vendor shall submit the data sheets duly filled to the maximum extent practicable. In addition, the following information shall be supplied:

a) Expected noise levels for the individual components of the train and the entire train.
b) Installation list of similar machines.
c) Details of the driver (if furnished by compressor manufacturer) including typical drawings, control details and applicable datasheets.

8.1.2 The vendor shall furnish a price list for spare rotors, bearings, seals and other components which are subject to wear.

8.1.3 The vendor shall outline in the offer all necessary special weather and seasonal protection required by the compressor, auxiliaries and driver (if furnished by compressor vendor) for startup operation and standstill. The vendor shall quote separately the protective items he proposes to furnish.

8.1.4 The offer shall include a separate proposal covering the services of the vendor's erection supervisor.

8.1.5 The offer shall include either a specific statement that all equipment is in strict conformity with the customer's specification or a specific list of deviations therefrom. The deviation may include alternative proposals to those specified.

8.2 Drawings

8.2.1 Each offer shall be accompanied by a preliminary outline dimensional drawing indicating the location of the inlet and discharge connection and the direction of rotation when viewing the compressor from the driver end.

8.2.2 Drawings showing details of construction including shaft sealing details, bearing details and internal construction shall be submitted with the offer.

8.2.3 When interstage coolers are furnished by the vendor, he shall provide data for the customer's heat and water balances and details of provisions for separation and withdrawal of condensate. The offer shall include drawings that show cooling system details.

8.2.4 Details and description of operation instrumentation and controls, as well as the makes, materials and type of auxiliary equipment's, shall be submitted.

8.3 Performance Curves

8.3.1 *Steam and Gas Turbine Driven Compressors*

The following performance curves for each compressor shall be included in the offer:

a) Discharge pressure, absorbed shaft power versus inlet capacity (from surge point to 115 percent rated capacity) of the compressor at specified inlet pressure, temperature and molecular weight of the gas at 80, 90, 100 and 105 percent of the rated speed.

b) Steam flow through the turbine under the above conditions based on normal steam conditions and steam flow at maximum power and under the most adverse steam conditions.

c) Fuel flow for the gas turbine under the above conditions based on normal fuel and site ambient conditions and fuel flow at maximum power and under the most adverse fuel and site ambient conditions.

8.3.2 *Motor Driven Compressors*

The following performance curves for each compressor shall be included in the offer:

a) Discharge pressure, absorbed shaft power versus capacity (from surge point to 115 percent rated capacity) of the compressor at specified suction pressure, temperature and speed. Absorbed shaft power shall include losses in the speed changer or the hydraulic coupling. Alternate operating conditions envisaging throttling shall be shown on the performance curve.

b) Torque to overcome friction and wind-age versus speed for the compressor including any gearbox, under normal starting conditions (closed suction) and including load torque with specified suction conditions for emergency starting (open suction).

c) Motor torque versus speed at rated voltage and 80 percent of rated voltage.

d) Motor current versus speed at rated voltage and 80 percent of rated voltage.

e) GD^2 for the compressor, gearbox and the motor referred to motor speed.

f) Estimated timings for acceleration for closed suction and open suction with 80 percent rated voltage unless specified otherwise.

8.4 Shipment

The shipment date shall be indicated in the vendor's offer and shall be reckoned from the date of receipt of order.

8.5 Warranty and Guarantee

Unless a specific exception is recorded by the vendor in his offer, it shall be understood that the vendor guarantees and agrees to the following:

a) The compressors shall be guaranteed for head, capacity and satisfactory performance and in every other respect at all specified operating points. The absorbed shaft power shall be guaranteed at the normal operating point (*see* Fig. 1).

   1) For variable-speed compressors, the head and capacities shall be guaranteed with the understanding that the shaft power may vary by ± 4 percent. The operating speeds specified in the offer are not guaranteed. But where changes in specified speeds are needed to meet the head requirements, the vendor shall adjust the operating range such that the new speed range is not closer to a critical or trip speed by the percentages indicated in **9.17.1**.

   2) For constant speed compressors, the specified capacity shall be guaranteed with the understanding that the head shall be within +5 and 0 percent of the specified one, the absorbed shaft power corrected to specified head-capacity conditions in accordance with the latest practice. Power test codes shall not exceed the stated shaft power by more than 4 percent. Pressure levels at side load conditions shall be guaranteed as agreed to between the customer and the vendor.

b) All equipment's and component parts shall be guaranteed by the vendor against faulty design, defective or improper materials, poor workmanship and failure from normal usage for one year after erection but not exceeding 18 months from the date of shipment. If any defects or malfunction occur during the guarantee period, the vendor shall make all necessary alterations, repairs and replacements free of charge (ex-works). Field labour charges for this shall be negotiated between the customer and the vendor.

9 BASIC DESIGN

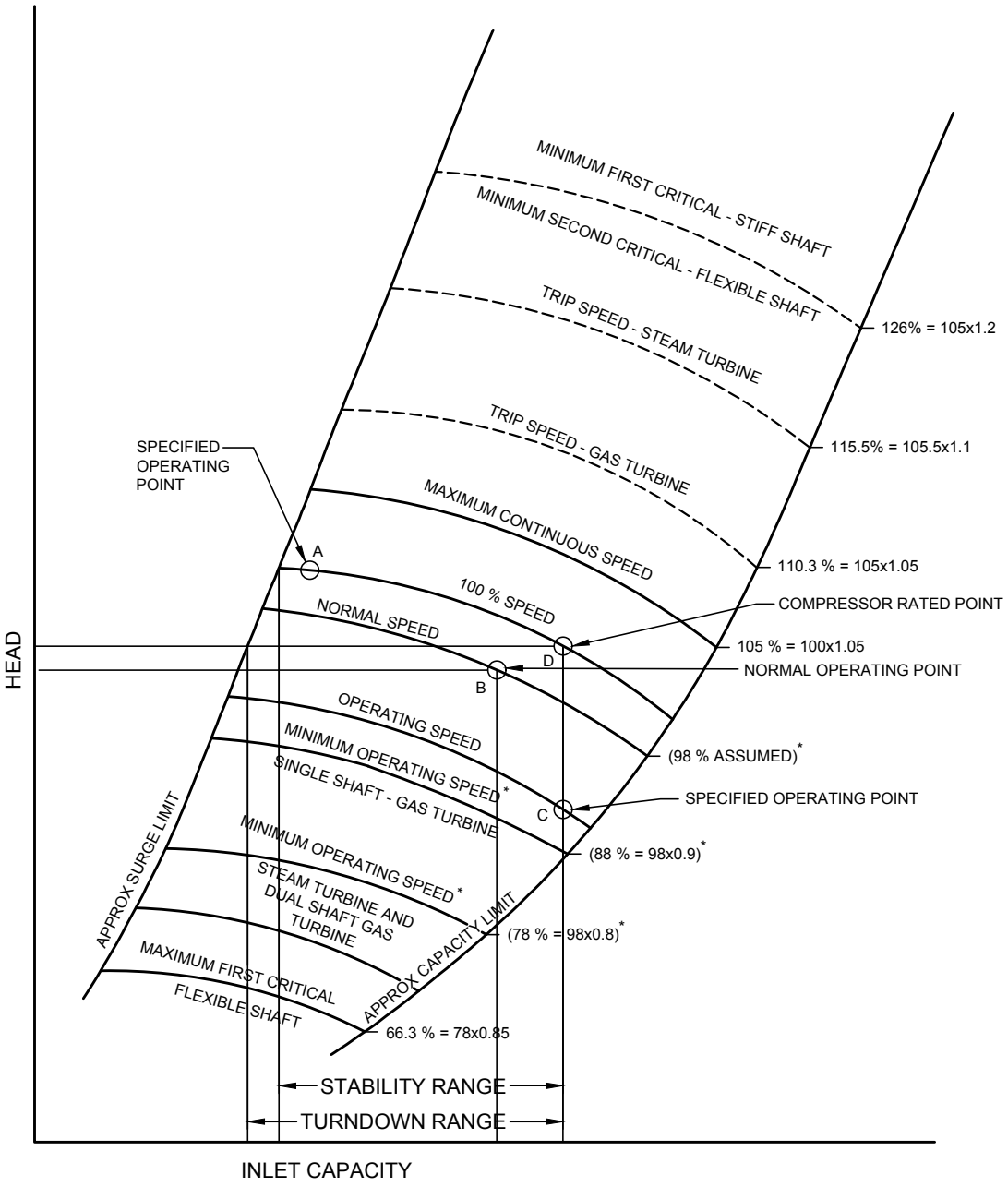
9.1 General

9.1.1 Compressors, drivers and auxiliaries shall be designed and manufactured suitable for continuous full load duty and shall be suitable for the specified operating conditions.

9.1.2 The head versus capacity characteristic shall rise continuously from rated point to surge. The compressor shall be suitable for continuous operation at any point at least 10 percent above the surge capacity without the use of a by-pass.

9.1.3 Cooling water systems shall be designed for not less than 6 bar working pressure, 0·6 bar pressure drop (maximum), an inlet water temperature of 33 °C, an 11 °C temperature rise and a fouling factor of 0·002 $Hr.Ft^2.^oF/BTU$ on the waterside, unless specified otherwise by the customer. Necessary provision shall be made for complete drainage.

9.1.4 The layout of the compressor installation, including auxiliaries shall be finalized jointly by the customer and the vendor to provide adequate clearances, access for operation and ease of maintenance.



NOTE 1 — The 100 per cent speed is determined from the head required for point 'A' and the capacity required by the compressor design to meet all specified operating points, such as 'C'.

NOTE 2 — The head-capacity curve at 100 per cent speed shall be extended to 115 per cent of capacity at 'D'. At other speeds, the head-capacity curve shall be extended to equivalent capacity corresponding to each speed that is, at 105 per cent speed it shall be extended to 1·05 × 1·05 times capacity at 'D', at 90 per cent speed it shall be extended to 0.90 × 1.15 times capacity at 'D'.

These points define the 'approximate capacity limit' curve.

* Assured values for illustration only.

FIG. 1 ILLUSTRATION OF TERMS

9.1.5 In the case of vertically split (barrel type) compressors, the inner casing or the diaphragm-motor package shall be designed such that they can be easily withdrawn from the outer casing and disassembled for inspection or replacement of parts. The vendor shall provide all special fixtures that may be required for withdrawal and disassembly of internals. Major components, such as casings and bearing housing shall be so designed as to ensure accuracy of alignment during reassembly.

9.1.6 Bearing housings, shaft end seals and housings that enclose rotating lubricated parts, instruments and controls shall be so designed as to minimize ingress of dust, moisture and other foreign matter during the period of operation as well as standstill.

9.1.7 The customer shall indicate in his enquiry data sheets whether the proposed installation is indoors (heated or unheated) or outdoors (with or without roof); and the weather conditions under which the compressor shall operate including minimum and maximum temperatures, condensation (if outdoors), usual dust problems and the like. The compressor and auxiliaries shall be suitable for the specified conditions. The vendor shall indicate in his offer any other special protection to be provided by the customer, for the latter's guidance.

9.1.8 Controlling the noise level of the installation shall be the joint effort of the customer and vendor. Noise levels shall be as agreed between the supplier and the purchaser. An acoustic enclosure shall be provided wherever required.

9.1.9 The customer shall advise the vendor at the time of enquiry itself about any specific requirements for liquid injection.

9.1.10 The customer shall specify and furnish, along with the enquiry, any local rules or regulations that will govern the supply.

9.1.11 Satisfactory performance of the compressor and its driver, as a combined unit, shall be the joint responsibility of the customer and the vendor. The combined unit shall perform substantially well on its permanent foundation as it did on the testbed in the vendor's shop. However, many factors like heavy piping loads/stresses, misalignment arising at operating conditions, deficiencies attributable to supporting structures, mishandling during transport and improper handling and assembly at the site can adversely affect site performance. In order to obviate the problems caused by these factors, the vendor shall provide the data required for properly designing the foundation and indicate the permissible values of pipe stresses and moments at the compressor flanges to the customer. In addition, the vendor's erection supervisor shall be present during the initial alignment check.

9.1.12 All electrical components shall be suitable for the area classification and grouping specified by the customer in his enquiry datasheets. Similar provisions shall apply to the lubricant, seal and oil system also.

9.2 Prime Mover

9.2.1 The customer shall specify, in his enquiry, the type of prime mover. The prime mover shall be sized and rated to meet the maximum operating conditions of the compressor and shall also include either gearbox or hydraulic coupling losses. The prime mover shall be in accordance with the specifications mentioned in the enquiry. The prime mover shall be suitable for satisfactory operation with the parameters specified. Anticipated process variations, if any, shall be indicated by the customer at the time of enquiry itself so that the prime mover is properly sized.

9.2.2 Unless otherwise specified, the type of protection provided to motors for auxiliary equipment shall conform to IS/IEC 60034-5.

9.2.3 Unless specified otherwise, steam turbine prime mover including auxiliary prime mover shall be capable of continuously developing 110 percent of the horsepower required for each of the customer's specified operating conditions while operating at the corresponding speed under specified steam conditions.

9.2.4 For motor-driven units, the motor rating (excluding service factor) shall be a minimum of 110 percent of the greatest power (including gear losses) required for any of the operating conditions.

9.2.5 Gas-turbine prime mover shall be sized by mutual agreement between the customer and the vendor.

9.2.6 Speed increasers and reducers shall be in accordance with IS 3681.

9.2.7 The customer shall specify the starting conditions of the compressor. Consideration shall be given to start the compressor at normal suction pressure. The method of starting shall be mutually agreed upon between the customer and vendor. Starting torque capabilities of the prime mover shall be adequate to meet the speed-torque requirements of the compressor.

In the case of electric motors, torque requirements shall be met at 80 percent rated voltage.

9.3 Casings

9.3.1 The casing thickness shall be adequate for the maximum working and test pressure and shall include a corrosion allowance of 3 mm minimum. The circumferential stress value in the casing shall be as agreed to between the manufacturer and the supplier. For cast materials, the factor given in the code shall be applied. Materials, casting factors quality and stress relieving of any welds shall be according to IS 2825.

9.3.2 The customer shall provide the system protection against the pressure that may be developed by the compressor while operating at the trip speed of the casing in his offer datasheets. The vendor shall indicate the design pressure.

9.3.3 Casing shall be made out of carbon steel or nodular iron for:

a) Air or non-combustible gas for working pressure beyond 21 bar;
b) Air or non-combustible gas at a calculated discharge temperature above 260 °C at any point, with the operating range at a maximum continuous speed. The maximum temperature is usually expected to occur near the surge point; and
c) Combustible or toxic gases.

9.3.4 For operating temperature between 30 °C and –100 °C, the casing material shall conform to the following specifications:

9.3.4.1 The steel shall be produced either by the open-hearth or electric-furnace process.

9.3.4.2 The steel shall have the following chemical compositions:

Carbon, *Max*	0·15 percent
Manganese	0·5 to 0·8 percent
Phosphorus, *Max*	0·04 percent
Sulphur, *Max*	0·045 percent
Silicon, *Max*	0·6 percent
Nickel	3·0 to 4·0 percent

9.3.4.3 Castings shall be normalized and tempered or liquid quenched and tempered. Casting shall be tempered at a minimum temperature of 593 °C and this temperature shall be effectively controlled by the use of pyrometers. If the manufacturer goes for liquid quenching and tempering to meet the impact requirements, all the castings shall be subjected to magnetic particle testing.

9.3.4.4 The notched bar impact properties of the material shall be determined by testing a set of three Charpy keyhole impact specimens at –100 °C test temperature. The average energy value of the three specimens shall not be less than 2 kg.m with no one value falling below 1.4 kg.m.

9.3.4.5 Tensile properties shall be as under:

Tensile strength, *Min*	448·3 N/mm^2
Yield point, *Min*	279·7 N/mm^2
Reduction of area, *Min*	35 percent
Elongation	24 percent

9.3.5 For operating conditions other than those specified in **9.3.3** and **9.3.4**, cast iron or other materials of construction may be offered.

9.3.6 Unless specified otherwise, casings shall be split vertically when the maximum working pressures of the casings, when handling hydrogen-rich gases, exceed the following:

Sl No.	*Molecular Percent, Hydrogen*	*Maximum Working Pressure of the Casing (bar)*
(1)	(2)	(3)
i)	100	15.0
ii)	90	16.5
iii)	80	18.5
iv)	70	21.0

9.3.7 Horizontally split casings shall employ a flat joint maintained tight by a suitable sealing compound. Gaskets shall not be used unless specific approval is obtained from the customer. The joints between the end covers and the casing cylinder of vertically split compressors shall be maintained securely by confined gaskets.

9.3.8 In order to facilitate alignments, disassembly and re-assembly, necessary vertical and horizontal jack screws, lifting lugs, eye bolts and guide dowels shall be provided. Whenever jack screws are provided as a means for parting contact faces, the mating face shall be countersunk to receive the jackscrew.

9.4 External Forces and Moments

When unusual features are noticed in the layout of piping systems, a special analysis may be required.

9.5 Bolting

9.5.1 Threading for pressure bolting shall be as per IS 4218 (Part 1 to 4) and IS 14962 (Part 2) or equivalent International Standard.

9.5.2 Tapped holes for bolting purposes shall be kept to a minimum on pressure parts. Studs are preferred to cap screws. Besides the corrosion allowance, sufficient material shall be left below the bottom of such holes in pressure sections to prevent leakage.

9.5.3 Adequate clearance shall be provided at bolting locations to permit the use of socket or box type wrenches. The vendor shall supply any special tools and fixtures required.

9.6 Casing Connections

9.6.1 Inlet and outlet connections shall be with flanges or studded bosses oriented as specified in the enquiry data

sheets and shall be suitable for the working pressures of the casing as specified in **9.3** unless agreed to otherwise by the customer. Inlet and outlet connections for barrel type compressor shall be located on the outer casing and not on the end covers.

9.6.2 Connections welded to the casing shall meet material requirements of the casing material rather than that of the auxiliary piping.

9.6.3 Flanged or studded boss connections of not less than 19 mm iron pipe size shall be provided for the following (*see* IS 4864 to IS 4870):

a) Vents,
b) Pressure and temperature gauge connections at each nozzle,
c) Liquid injection,
d) Casing drains,
e) Water cooling,
f) Lube and seal oil, and
g) Flushing.

Casing drains for horizontally split casings shall be provided at the lowest point of each stage or at other lower points.

9.6.4 Casing drains on vertically split casings shall be studded bosses. They shall be located at the lowest point of each inlet section, the section between the inner and outer casings and the discharge section.

9.6.5 Where flanged or studded openings cannot be provided for oil and inflammable or toxic gas connections, threaded openings in sizes 9 to 38 mm are permissible. Pipe nipples, preferably not longer than 150 mm shall be screwed and seal welded to the threaded openings and shall be provided with a flange. Pipe nipples shall be a minimum of schedule 160 for sizes 1 and below and schedule 80 for size 1.5.

9.6.6 Openings for pipe sizes 32, 64, 89, 127, 178 and 228 mm shall not be used.

9.6.7 Flanged connections shall conform to IS 1536 or IS 1537 as applicable, cast iron flanges shall be flat-faced. Face and drilling requirements shall also apply to studded connections for which studs shall be furnished. Flat-faced flanges are acceptable on steel casings also with the customer's approval. Thicker and larger outer diameter flanges are also acceptable. If the vendor uses flanges other than those covered by IS 4864 to IS 4870, all required mating parts shall be supplied by the vendor and details of connections shall be approved by the customer.

9.6.8 Threaded connections shall not exceed R 40. Tapped openings and bases for pipe threads shall conform to IS 554.

9.6.9 Tapped openings that are not connected to piping shall be closed with solid steel plugs. Plugs that may require subsequent removal shall be of corrosion-resistant material.

9.7 Auxiliary Piping

9.7.1 Auxiliary piping systems shall include all necessary lube oil, seal oil, control oil, balance gas, drain, vent steam and water lines that are relevant to the compressor, the prime mover and the auxiliaries. Auxiliary piping also includes valves, controls, pressure reducers, thermometers, pressure gauges or instrumentation on the compressor unit.

9.7.2 The auxiliary piping within the confines shall be furnished by the vendor. Interconnecting piping between the unit and other auxiliaries shall be furnished by the customer. Piping within the confines of the main unit or base plate shall terminate with flanged connections. Piping shall be routed keeping in view proper flexibility, and easy access for operation, maintenance and cleaning. Small piping shall be suitably secured to minimize vibration and eventual breakage.

9.7.3 Oil drains shall be sized to run no more than half full and arranged in such a way that good draining is ensured (considering the possibility of foaming conditions). Horizontal runs shall slope continuously, a minimum of 25 mm for every metre, towards the reservoir.

9.7.4 The piping specifications of IS 1570 (Part 5) and IS 1239 (Part 2) apply to all piping mounted on either the compressor unit or the base plate or both.

9.7.5 Instrument lines carrying combustible or toxic gas or oil shall be provided with a shut-off valve at the point of measurement.

9.7.6 Interstage gas or air piping furnished by the vendor shall conform to IS 1570 (Part 5) and IS 1239 (Part 2).

9.8 Impellers

9.8.1 Impellers can be semi-open, consisting of disc and vane or closed, consisting of disc, vanes and cover. Impellers shall be cast, or of riveted, welded or electro-eroded construction. Other methods such as brazing shall be permitted if approved by the customer.

9.8.2 Welded and riveted impellers may consist of the cast and forged components. Welds in the gas passages shall be smooth and free from weld spatter. After welding, the impellers shall be heat-treated and stress-relieved. Vanes integral with the disc or with the cover shall have a minimum fillet of 3 mm or one half the passage width (whichever is less). Vane entrances and exits shall not have sharp edges.

9.8.3 Cast impellers shall be finished 'all over' except for gas passages. Welding shall be prohibited for balancing. Welding for any other purpose will be permitted only with the customer's approval.

9.8.4 Impellers shall be shrunk assembled on the shaft with or without the key. Other methods may be acceptable with the customer's approval. Keyway fillets shall be not less than 1.5 mm.

9.8.5 The vendor's offer data sheets shall describe in detail the type and material of construction of impellers.

9.9 lnterstage Diaphragms and Inlet Guide Vanes

9.9.1 Interstage diaphragms shall be suitable for all specified operating conditions including startup, shut-down, settling out and momentary surge. When intermediate main connections are employed, the customer shall specify the maximum differential pressure. Internal joints shall be designed in such a way as to minimize leakage and still permit easy disassembly.

9.9.2 If diaphragm cooling is specified, top and bottom halves of horizontally split diaphragms shall have independent cooling passages. Each inlet and outlet connection for the coolant shall be manifolded at the top and the bottom of each casing.

9.10 Labyrinths

In order to minimize internal leakage, renewable labyrinths shall be provided at all internal close clearance points. Preferably, these labyrinths shall be stationary and easily replaceable.

9.11 Balance Line and Drum

9.11.1 A balance drum, line and opening (or equivalent, if required) shall be provided to minimize the axial loads on thrust bearings. A separate tapping shall be taken to indicate the pressure in the balancing chamber. The vendor shall specify the operating limits.

9.11.2 Compressor designs that do not require a balance drum are acceptable with the customer's approval.

9.11.3 The balance line shall be sized to handle balance piston labyrinth gas leakage at twice the initial clearance, without exceeding the load rating of thrust bearings.

9.12 Shafts and Shaft Sleeves

9.12.1 Shafts shall be made of one-piece, heat-treated, forged steel and shall be suitably ground.

9.12.2 Coupling fits shall be tapered, with dimensions as agreed between the manufacturer and the purchaser. Tapers may be less for hydraulically fitted couplings. Cylindrical shaft arrangement can be agreed upon between customer and vendor.

9.12.3 Renewable shaft sealings or their equivalent shall be furnished at interstage close clearance points, under all carbon ring packings and for gas service at the shaft seals, unless other shaft protection is approved by the purchaser. These sleeves shall preferably be made of corrosion-resistant materials suitably hardened to resist wear and shall be sealed to prevent leakage between the shaft and the sleeves.

9.13 Bearing and Bearing Housing

9.13.1 Radial bearings shall be precision bored and of the journal or tilting pad type with steel-backed renewable babbit liners, pads or shells. The bearing liners, pads or shells shall be replaceable without removing the top half of the casing of the horizontally split compressor or the end covers of the vertically split unit. Bearings shall be designed to maintain a stable oil film at any operating speed.

9.13.2 Thrust bearings shall be of multiple segment type designed for thrust in both directions. The sizing of thrust bearings shall take into account the thrust loads from the compressor and the thrust required to slip the coupling with a friction coefficient of 0.25. Reserve on the thrust bearing capability shall permit operation of the unit with some degree of fouling. The thrust bearing shall be adjustable for positioning the rotor axially. Thrust collar, which revolves with the shaft, shall be replaceable, shrunk and positively locked to the shaft to prevent fretting.

9.13.3 Radial and thrust bearings shall be designed for pressure lubrication and shall be so arranged as to minimize foaming. Drain openings shall be adequately sized and designed to ensure proper drainage.

9.13.4 Non-pressurized, horizontally split bearing housings shall be furnished either separate from or integral with the casing. The customer shall specify if contamination of the gas or lube oil is a factor to be considered.

9.13.5 The compressor shall be so designed as to provide access for shaft measurements which are taken with a handheld probe adjacent to each radial bearing.

9.14 Provision for Detectors

9.14.1 Provision shall be made in each bearing housing for mounting two radial vibration measurement probes 90º apart. Preferably, one probe shall be mounted in the predominantly horizontal plane and the other in the predominantly vertical plane. The horizontal probe shall be located to lead the vertical probe in terms of the direction of rotation of the shaft. Provision shall be made for one axial displacement probe at the thrust bearing end of each casing. The vendor shall indicate by illustration the actual location (in degrees) of all probes. All probes shall be of the non-contact type.

9.14.2 Radial probe provision shall be located such that the probe will sense an unplated ground surface having not more than 0.012 7 mm mechanical runout and minimum electrical run out (*see* **9.18.5**). Probe provision shall be located such that the oil spill is minimized while changing. All vibration probes shall be enclosed inside the bearing housing for weather protection of the shaft sensing area. Probe provision shall be suitable for external mounting as described in **9.14.3**, with the only exception of axial position on a drive through casing.

9.14.3 Probes shall be furnished if specified and shall be installed in movable holders. Each holder shall be shouldered so that the correct probe location is maintained when the probe is removed and reinstalled. The holder shall be mechanically locked to the bearing housing and the probe itself shall be mechanically locked in the holder to prevent loosening during normal service. A junction or terminal box shall be mounted on the probe holder. The holder and the box assembly shall be removable as a unit, while the compressor is in service.

9.14.4 Oscillator-detectors and inter-connecting wiring between probes and detectors shall be furnished if specified. The wiring shall be in a conduit. Standardized cable lengths shall be used on a compressor prime mover train. Detectors, wiring and probes furnished by the vendor shall be replaceable without the need for field calibration.

9.14.5 If specified, read-out equipment shall be furnished, the characteristics of which match with that of the detector-probe system and does not require field calibration. Vibration matter scales shall have 0·130 mm span with 0·005 mm scale divisions. Axial displacement indicator scales shall have a –0·635 to +0·635 mm span, with '0' at the centre, scale divisions shall be 0·025 mm.

9.15 Shaft Sealing

9.15.1 Shaft ends shall be provided with seals to prevent leakage outwards of or into the compressor over the range of specified operating conditions and during periods of standstill. The offered seals shall be suitable for variations in suction conditions that may prevail during start-up and shutdown or any special operation specified by the customer.

9.15.2 Unless otherwise agreed, shaft seals shall be accessible for inspection and for replacement, without removing the top half of the casing of the horizontally split compressor or the end covers of the vertically split unit.

9.15.3 Shaft seals may be one or a combination of the following types as specified by the customer on the enquiry datasheets. The materials for component parts shall be suitable for the service indicated. Provision shall be made in the seal design for injecting buffer gas. The customer shall specify at the time of enquiry whether buffer gas is to be used.

a) *Labyrinth type* — This type (Fig. 2) may include carbon rings, in addition to the labyrinths, if approved by the customers. Ejection or injection systems, wherever required, shall be furnished complete with piping, regulating and control valves, pressure gauges, strainers and the like with each item piped and valves to permit its removal during normal operation Whenever the gas tapped from the compressor discharge is the motivating fluid for the ejector, the additional provision shall be made for sealing during start-up and shut-down.

b) *Mechanical (contact) type* — This type (Fig. 3) shall be provided with labyrinths and oil slingers to minimize leakage of oil to the atmosphere or into the compressor. Oil or any other suitable liquid furnished under pressure to the rotating faces may be supplied from the lube oil system or an independent seal oil system. Reference may be made to IS 8593 (Part 1).

   Oil that comes in contact with the gas shall be discarded if it is considered harmful to such components as bearings and couplings. Additional supplementary devices may be provided to ensure sealing when the compressor is at a standstill and the seal oil system is shut down. The customer shall specify in his enquiry whether such devices shall be provided.

c) *Restricted ring-type* — This type (Fig. 4) shall include rings (of carbon or any other suitable material) mounted in retainers or spacers. The seal may be operated dry or with a sealing liquid or buffer gas.

d) *Liquid film type* — This type shall be provided with metallic sealing rings or sleeves or labyrinths to minimize leakage of oil to the atmosphere and into the compressor. A sealing liquid shall be supplied. Liquid film type seals may be of the cylindrical bush type (Fig. 5) or of the pumping type (Fig. 6).

e) *Dry gas seals* — These are non-contacting, dry-running mechanical face seals that consist of a mating (rotating) ring and a primary (stationary) ring. When operating, lifting geometry in the rotating ring generates a fluid-dynamic lifting force causing the stationary ring to separate and create a gap between the two rings.

9.15.4 The design of oil seal components shall be such that they shall not adversely affect the rotor stability.

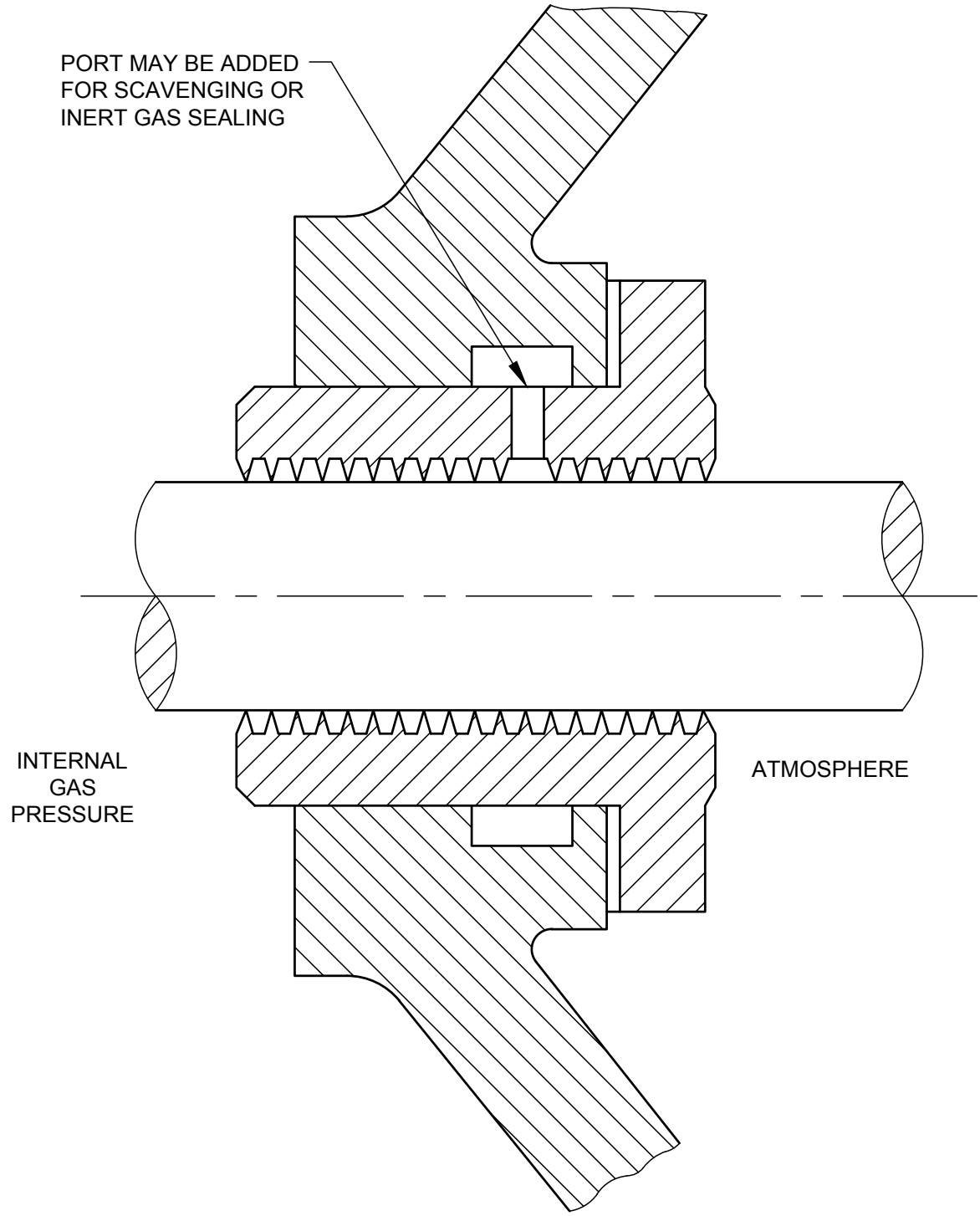


FIG. 2 LABYRINTH SHAFT SEAL

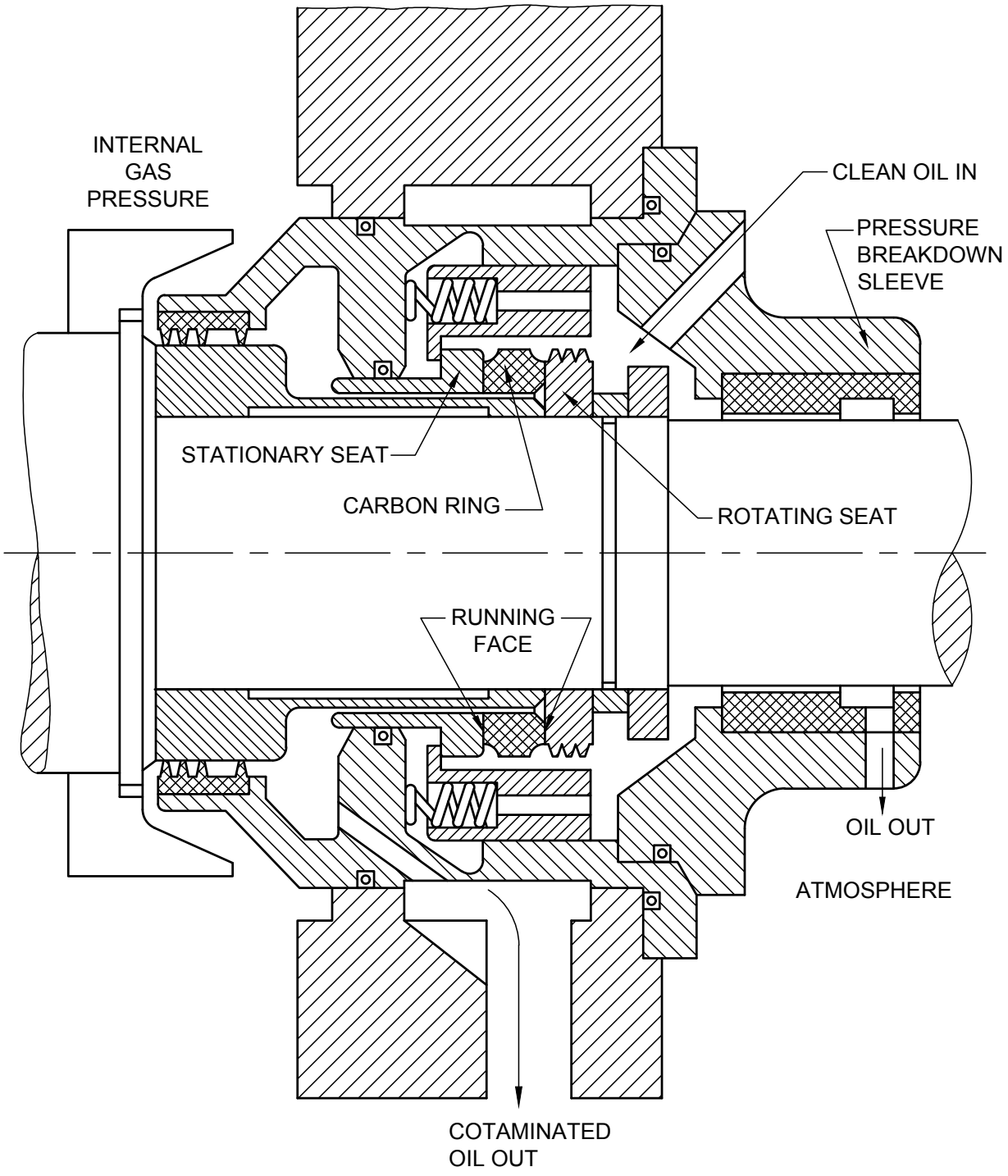


FIG. 3 MECHANICAL (CONTACT) SHAFT SEAL

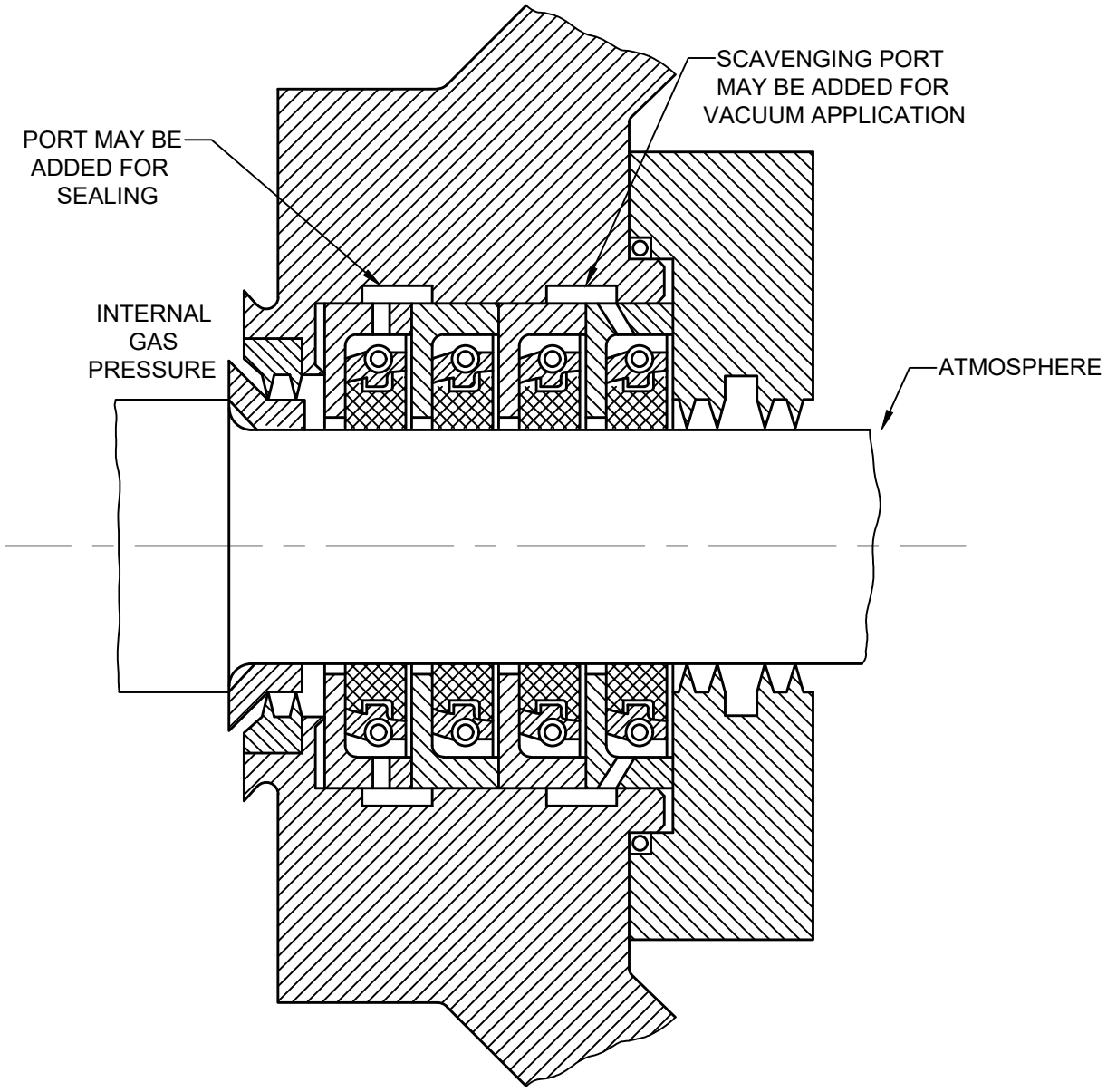


FIG. 4 RESTRICTIVE - RING SHAFT SEAL

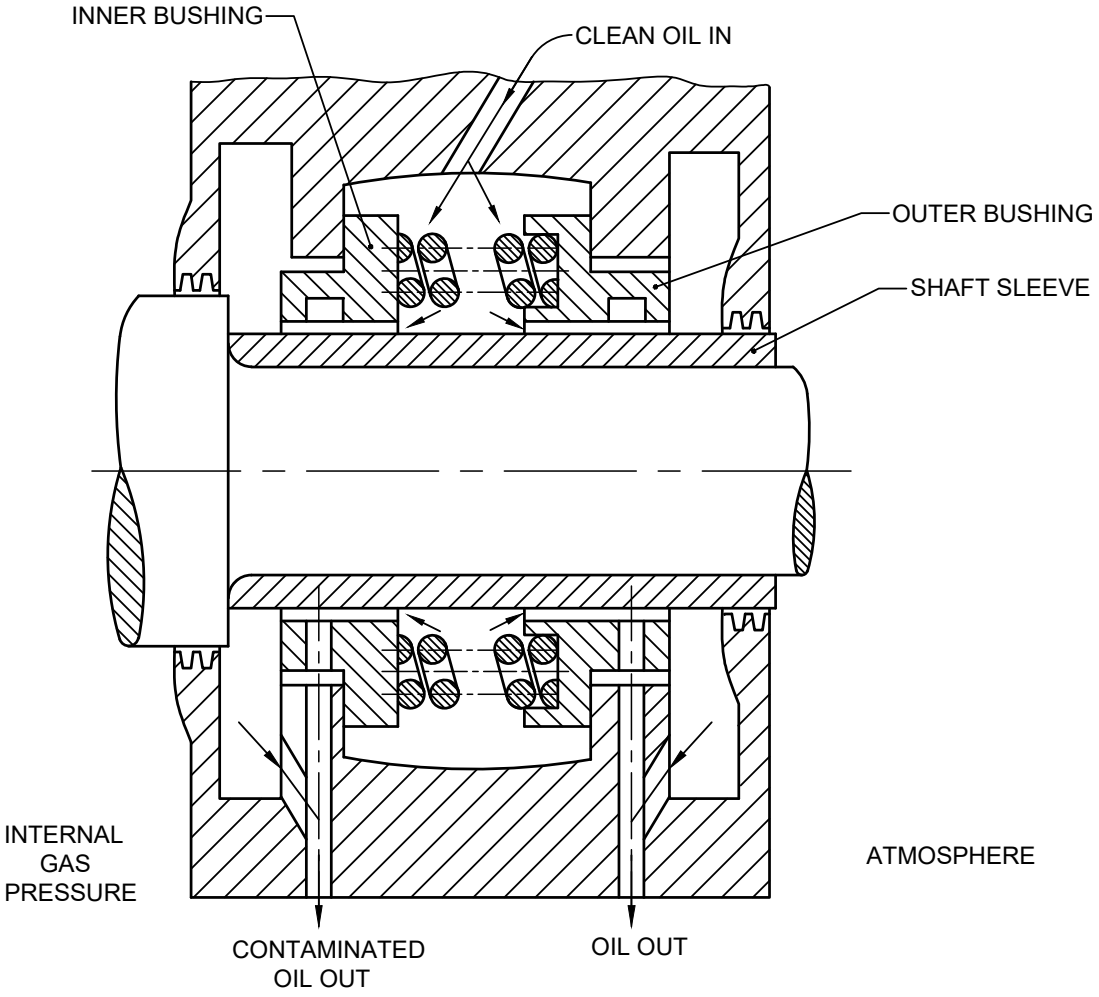


FIG. 5 LIQUID-FILM SHAFT SEAL WITH CYLINDRICAL BUSHING

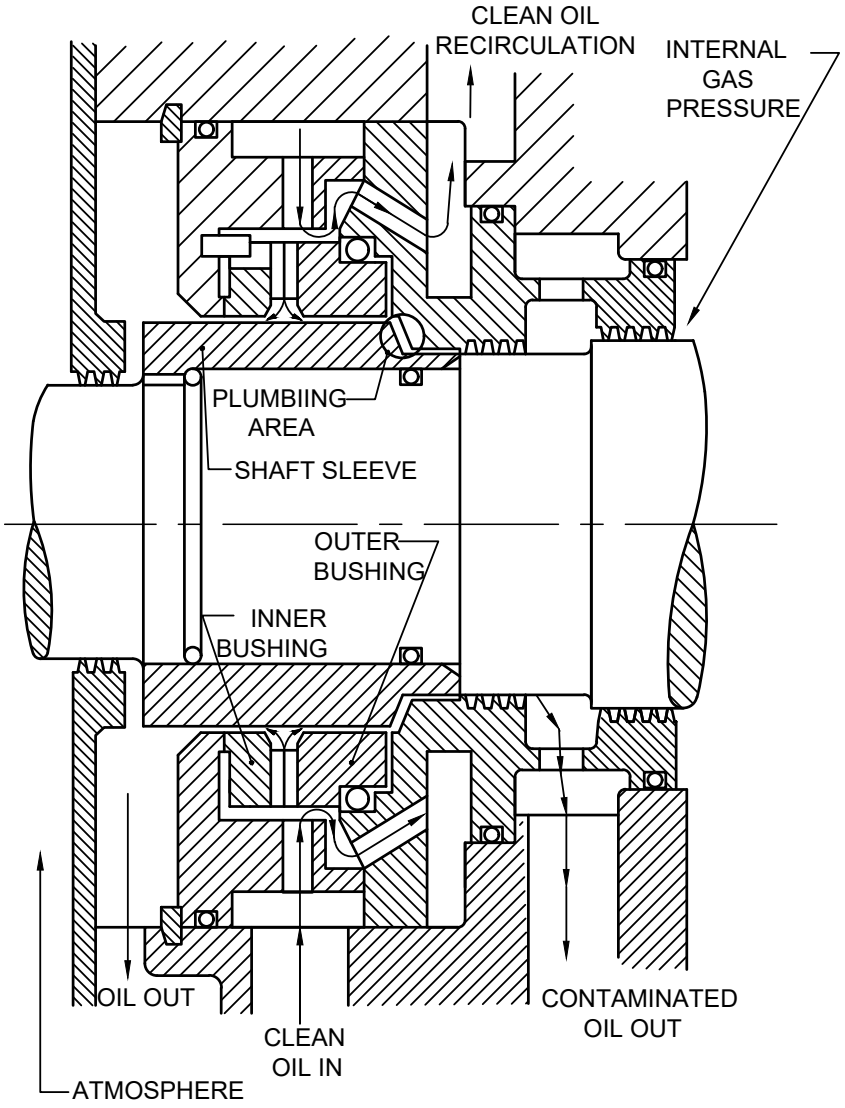


FIG. 6 LIQUID - FILM SHAFT SEAL WITH PUMPING BUSHING

9.15.5 The customer shall specify on the data sheets whether the seal oil system and the lube oil system shall be independent or a combined one. If independent systems are specified, the vendor's proposal shall describe the details of the means to be provided for preventing the interchange of oil between the two systems.

9.16 Couplings

9.16.1 Connections between the compressor, drive and gear unit shall be by suitably forged steel, flexible, spacer type couplings. The customer and the vendor shall mutually agree upon the make, type and the supplier (compressor or prime mover manufacturer) of the couplings.

9.16.2 Coupling spacers shall be made from one piece of forged steel and not fabricated from multiple forgings. They shall be of sufficient length to permit:

a) removal of either half of the coupling,

b) removal of bearing parts required for access to the seals, and

c) removal and replacement of such renewable circumferential parts as seal rings and complete seal units.

These removals shall be possible without removing the rotating elements of the unit.

9.16.3 The couplings and spacers shall be dynamically balanced without the rotating assembly to a tolerance

suitable for maximum continuous speed. The coupling hubs, sleeves and spacers shall be suitably match marked. Bolting shall be selected by weight to enable interchanging without altering the balance.

9.16.4 Removal guards shall be provided at all non-closed couplings. The guards shall be of a sufficiently heavy and rigid design to avoid contact with the coupling or the shaft as a result of bodily contact. The guards shall be designed so as to prevent drain oil from the adjacent bearing housing.

9.16.5 External feed and drain oil lines for lubricating couplings shall be classified as auxiliary piping. Covers for the continuous oil lubricating couplings shall be leak-proof and shall be designed to promote proper drainage to prevent foaming.

9.16.6 Sleeve bearing motors shall be provided with limited end float couplings which shall prevent the motor rotor from rubbing either bushing. The maximum thrust that the motor will develop, shall be indicated by the motor manufacturer and shall be taken care of by the gear unit if provided or by the compressor when a gear unit is not provided.

9.16.7 The prime mover half of each coupling shall be furnished, with a balanced idling adapter, wherever necessary, to permit uncoupled operation.

9.16.8 Couplings and mountings shall be tapered fit for the compressor valves. Fittings for the tapered shafts shall have dimensions as agreed between the manufacturer and the purchaser.

9.16.9 Coupling hubs shall be provided with suitable puller holes.

9.17 Critical Speeds

9.17.1 The first lateral critical speed (actual value) of stiff shaft compressors shall be at least 20 percent above the maximum continuous speed. Flexible shaft compressors shall operate with the first critical speed at least 15 percent below any operation speed. The second lateral critical speed shall be at least 20 percent above the maximum continuous speed. Wherever operating conditions require reduced operating speeds, careful consideration shall be given to the location of the first critical speed. The compressor vendor shall carry out a lateral critical speed analysis and determine that the critical speeds of the prime mover are compatible with those of the compressor and that the combination is suitable over the entire operating speed range. The vendor shall indicate in the summary report his assumptions regarding bearing and support stiffness used for calculating the lateral criticals.

9.17.2 The vendor shall perform a composite torsional vibration analysis of the compressor prime mover unit and shall be responsible for the satisfactory performance of the unit. Other manufacturers furnishing components in the system shall provide all necessary data of the vendor and shall identify the source of torsional excitation:

a) Actual torsional resonant speeds shall not be with 10 percent of the first and second harmonic of the rotational frequency in the operating speed range up to trip speed.
b) Actual torsional resonant speeds shall not be within 10 percent of gear tooth passing frequencies within the operating speed range.

9.17.3 In such systems where it may so happen that conditions indicated above cannot be satisfied, the system is considered acceptable as long as the calculated torsional stresses at resonant speed are within the stress values permissible for the shaft material.

9.18 Vibration and Balance

9.18.1 Major parts of the rotating element, such as shafts, impellers, balancing drum, etc. shall be individually balanced both statically and dynamically conforming to ISO 21940-11 or equivalent.

9.18.2 The rotating element shall undergo multi-plane dynamic balancing during assembly. This shall be accomplished after the addition of not more than two major elements to a flexible rotor having a normal speed above 6 000 rpm. Rotors with normal speeds of 6 000 rpm and below shall have a minimum of three balancing planes. Balance correction shall be applied only to new elements. Elements already balanced shall not be disturbed, only rotors with single keys for coupling shall be balanced with the half key in position. The maximum permissible unbalanced force at any journal, at a maximum continuous speed, shall not exceed 10 percent of the static loading of that journal.

9.18.3 After completing the final balancing of the rotating element assembly, the sensitivity of the balancing machine system shall be checked. If the same is either marginal or unacceptable, the rotating elements shall be re-balanced on a more sensitive machine.

9.18.4 During the shop test of the assembled compressor, operating at maximum continuous speed or any other speed within the specified operating range, the double amplitude of vibration in any plane measured on the shaft adjacent and relative to each radial bearing shall not exceed the following value or 50 μm, whichever is less:

$$\text{Double amplitude (including runout)} = \frac{7\,740\,000}{\text{rpm}} \ \mu\text{m}$$

where rpm is the maximum continuous speed expressed in revolutions per minute. At the trip speed of the compressor prime mover, the vibration shall not exceed this value by more than 12·5 μm.

9.18.5 Besides the shaft runout referred to above, if the vendor can demonstrate that electrical runout due to shaft material anomalies are present, this may be added to the permissible vibration level up to a maximum of 6·5 μm, provided a handheld probe gives results not exceeding the normal limit.

Electrical runout can be established by rolling the rotor slowly on bearings or vee blocks while measuring runout width using a proximity probe and a dial indicator at the same location of the shaft.

9.19 Mounting Plates

9.19.1 The compressor shall be furnished with sole plates or a base plate, as specified by the customer on the enquiry datasheets. The equipment to be mounted shall be provided with machined levelling surfaces and vertical jackscrews, the feet of the equipment shall be drilled with pilot holes for use in final dowelling. Both types of mounting plates shall be furnished with horizontal jackscrews to facilitate positioning the major equipment, The horizontal jackscrew arrangement shall be capable of overcoming the friction force required to move the fully assembled pieces of major equipment for achieving acceptable levels of shaft alignment without calling for the use of sledgehammers, hydraulic jacks, chain falls, etc.

Mounting plates shall not be drilled for the equipment to be mounted by others. Anchor bolts shall be furnished by the vendor.

9.19.2 The compressor base plate shall be a single unit fabricated out of carbon steel. It shall include the following features:

a) If specified, the base plate shall be extended, as required, to support the driver, gearboxes (if any) besides the compressors. A single unit base plate shall not preferably exceed 8 metres in length and 4 metres in width.

b) The customer shall specify whether the base plate shall be suitable for column mounting.

c) The base plates shall be provided with an adequate number of lifting lugs. The base plate shall have adequate rigidity to withstand the loads use to major pieces of equipment coming on it.

The customer shall indicate in his enquiry data sheets whether the base plates shall be suitable for lifting together with the equipment.

d) Pedestals and base plate shall be rigid enough to permit the use of horizontal jackscrews and to withstand the maximum forces and moments of the piping attached to the equipment mounted thereon, without adversely affecting the shaft alignment.

e) The bottom of the base plate between the structural members shall be exposed and access for grouting under the base plate shall be provided. The resting pads at the bottom of the base plate shall be in one plane to enable the use of a single level foundation with continuous grouting under the notch of the base plate. A sub-sole plate, if required, shall be provided by the vendor.

f) Levelling surfaces and vertical jackscrews shall be provided on the base plate.

g) Oil reservoirs shall be separate from the base plate unless approved otherwise by the customer.

h) When specified by the customer, decking shall be provided and the top of the base plate covering walkways and work areas.

10 MATERIALS OF CONSTRUCTIONS

10.1 General

10.1.1 Unless specified otherwise herein or on the customer's data sheets, the material of construction shall be as per the manufacturer's standard for the specified operating conditions. Annex C lists material specifications which when used with appropriate heat treatment or impact tests, or both, will ensure the selection of materials generally considered acceptable for major component parts. The method of manufacture (such as casing, forging or fabrication of all major components) shall be clearly indicated in the vendor's offer datasheets.

Materials shall be identified by reference to appropriate specifications, type numbers or the like. When it is not possible to give appropriate designations, the manufacturer's code or trade name may be used. In such cases, the manufacturer shall be identified and the chemical composition and significant physical properties of the material shall be indicated in the offer datasheets.

Copper and copper-bearing alloys (excluding monel, bearing and precipitation-hardened stainless steel) shall be used for compressors or auxiliaries, which are in contact with corrosive gases or gases capable of forming explosive copper compounds.

10.1.2 Selection of casing material shall be governed by the limits imposed by **9.3.3, 9.3.4** and **9.3.5**. For steel casing, bolted-on bearing housing and bearing supports shall also be out of steel.

10.1.3 While selecting materials for compressors, which handle gases specified to contain hydrogen sulphide, the hardness of the impellers, shaft seals, internal bolting and other stressed parts, shall not exceed 22 HRC unless specified otherwise. Components fabricated by welding shall be heat-treated so that both the weld and heat-affected zones meet this hardness limitation.

10.1.4 External parts subjected to rotary or sliding motions such as guide vane actuator linkage shall be out of non-rusting materials suitable for the location.

10.1.5 The material quality requirements (minimum) of bolting for pressure joints shall be of carbon steel St-37 according to IS 1570 (Part 1) for cast iron casings and high-temperature alloy steel 40CrlM28 for steel castings. Nuts shall conform to St-37. For temperatures below – 30 °C suitable low temperature bolting material shall be used.

10.2 Quality Standards

10.2.1 Cast steel casings shall conform to the following requirements:

a) All cast steel casing parts shall be subject to magnetic particle examination as agreed to between the manufacturer and the purchaser.
b) All welds for steel pressure castings shall be made by qualified operators and by procedures in accordance with IS 6916. The compressor manufacturer shall be responsible for the review of all the repairs and repair welding to ensure that they are properly heat-treated and examined non-destructively for soundness and compliance with specification requirements.
c) Major repair welds for ferritic steels shall be given stress relief heat treatment unless agreed to otherwise by the customer. Magnetic particle inspection shall be performed on all repair welds in accordance with IS 5334.

10.2.2 Fabricated casings made from wrought material or combinations of wrought and cast materials shall conform to the following requirements:

a) Welding qualifications shall be in accordance with IS 817.
b) Plate edges shall be inspected by a magnetic particle or a liquid penetrant examination.
c) All accessible surfaces of the welds shall be inspected by a magnetic particle or a liquid penetrant examination after back chipping or gauging and after stress relieving.
d) All pressure containing welds, including flange nozzle and casing circumferential welds, shall be full penetration welds connecting main flanges to shells of horizontally split casings.
e) All fabricated casings, irrespective of thickness, shall be post-weld heat-treated.

10.2.3 Forged steel casings and end covers shall be in accordance with IS 2644.

10.2.4 All accessible areas of welds on welded impellers shall be inspected by a magna-flux or dye-penetrant examination. Cast impellers shall pass the vendor's spot radiographic examination before finish machined; radiographs shall be taken at all points of critical stress. Each impeller shall be subjected to an over-speed test of at least 115 percent of synchronous speed if the compressor is motor-driven, or 115 percent of maximum continuous speed for variable speed units. After the over-speed test, each impeller shall be examined all over by means of magna-flux or liquid penetrant methods.

10.2.5 Reports of all heat treatment and radiographs, fully identified, whether carried out during the normal course of examination or as a part of a repair procedure, shall be preserved for five years for review by the customer.

11 LUBE AND SEAL OIL SYSTEMS

11.1 A complete pressure oil system shall be furnished by the vendor with each compressor unit to supply oil at a suitable pressure, as applicable, to the:

a) bearings of the compressor, driver and gearboxes, if any, unless specified otherwise;
b) couplings, if lubricated continuously;
c) turbine governor, the trip and throttle valve;
d) customer's control, system (if hydraulic); and
e) seal oil system.

11.2 Unless specified otherwise, IS 8593 (Part 1) shall apply.

11.3 The requirements of the dry gas seal system shall be specified by the purchaser in the enquiry document.

12 CONTROLS AND INSTRUMENTATION

12.1 The vendor shall provide sufficient data on compressor performance to enable the customer to properly design a control system for start-up operation, for all specified operating conditions and surge prevention. The vendor shall review the customer's overall control system for compatibility with the vendor-furnished control equipment if requested by the customer.

12.1.1 The oil system shall be suitable for orderly start-up, stable operation, warning of abnormal conditions, and shut-down of the main equipment in the event of impending damage.

12.1.2 All control, valves, relief valves, solenoid, bellows, and diaphragm-operated valves, and all other valves handling flammable or toxic fluids shall have steel bodies with stainless steel internals and trims. Control heads for flammable fluids shall be made of steel.

12.1.3 Controls and control panels shall be completely piped, requiring only the purchaser's external piping connections.

12.1.4 Controls and control panels shall be completely wired, is required for controls or instrumentation,

wiring to all items when more than one wiring point shall be provided from a terminal box. All wiring shall be installed in protective metal conduits or enclosures.

12.1.5 All controls and instruments shall be located and arranged for ease of visibility by the operators as well as for accessibility for tests, adjustments and maintenance.

12.1.6 Valved bleeders are required between instruments and their valves for service over 15 bar.

12.1.7 When failure or malfunction of a reducing valve may cause overpressure and resultant hazard or damage to downstream equipment or components, a relief valve discharging to the reservoir shall be furnished.

12.2 Panels

12.2.1 At least one instrument panel for the oil system shall be provided by the vendor when specified. The vendor shall furnish and mount on or in the panels the instruments specified on the datasheets. Spaces or cutouts, or both, shall be supplied as specified for the purchaser's instruments. The configuration of the panels shall be as specified.

12.2.2 The types of instruments and the locations of the panels shall be specified by the purchaser.

12.2.3 After all the equipment locations have been fixed, the pressure instruments shall be piped to the terminal locations specified by the purchaser. A shut-off valve within each panel shall be provided for all lines except those for shutdown sensing devices.

12.3 Alarms and Shut-downs

12.3.1 The vendor shall furnish as a minimum the following alarm and shut-down contacts (or pearing metal temperature detectors). The alarm setting shall precede the shut-down setting:

12.3.2 A separate housing shall be furnished for each pressure or temperature-sensing switch. Single pole, double-throw switches shall be used.

12.3.3 'Open' (de-energize) to alarm and 'close' (energize) to trip electric switches shall be furnished.

12.3.4 The vendor shall furnish a 'first out' type of annunciator when an annunciator system is specified.

12.3.5 All instruments and controls other than shutdown sensing devices shall be installed with sufficient valving to permit removing instruments and controls while the system is in operation.

12.3.6 Piping to a pressure transmitter for alarms shall include an orifice, a T-connection, a pressure gauge, and a bl9eeder valve to test the alarm. The arrangement of the shutdown sensing device shall permit it's being checked during the operation where a redundant system (such as a two-out-of-three system) is employed. The alarm and shutdown transmitter setting shall not be adjustable from outside the housing. Pressure elements shall be made of 18 chromium-8 nickel (18Cr8Ni) stainless steel.

12.4 Thermometers

Industrial thermometers or dial bimetallic or mercury-filled thermometers of suitable size shall be mounted in the oil piping of the cooler inlets and outlets and in the oil piping of the outlet of each radial and thrust bearing. Individual 18Cr8Ni stainless steel wells shall be furnished in pressurized or flooded locations.

12.5 Pressure Gauges

12.5.1 Pressure gauges shall be furnished at the discharge of each oil pump, at each bearing and seal inlet oil header, and at the control inlet oil header.

12.5.2 Each pressure gauge shall have a 100 mm minimum size dial, a NPS male connection, and a

	Alarm	Shut-down
Low lube-oil pressure for each level …….....	×	×
Low level in the reservoir for each item ……	×	…
Low seal oil level or low seal oil differential pressure for each item ……..	×	×
High overhead-tank level for each item ……...	×	…
High thrust-bearing oil or metal temperature for each item (purchaser shall specify the arrangement required) ……..	×	…
Standby pump running for each item (not required if the purchaser's alarms one from the motor starter) ……	×	…
High oil-filter differential pressure for each item ……..…	×	…

18Cr8Ni stainless steel bourdon tube and movement. Each gauge shall be suitably valved to permit its removal while the system is in operation.

12.6 Flow-indicators

12.6.1 Flow-indicators shall be furnished in the atmospheric oil-drain return line from each bearing, gear, and seal and in either the pressured inlet piping or the outlet piping of each continuously lubricated coupling.

12.6.2 Steel non-restrictive flow indicators shall be used for atmospheric drain lines. Steel restrictive flow indicators shall be used for pressured lines.

12.6.3 Each flow indicator shall be of the 'bull's eye' type and shall be installed with its butt's eyeglass preferably in a vertical plane to facilitate viewing the flow of oil through the particular line.

12.6.4 All instrumentation and controls shall be suitable for outdoor installation unless specified otherwise.

12.6.5 All solenoids shall have continuous duty ratings.

12.7 Types of Control Systems

12.7.1 The compressor may be controlled on the basis of the inlet pressure, discharge pressure, flow or some combinations of these parameters. The control system may be mechanical, pneumatic, hydraulic, electrical or any combination thereof. The system may be manual or automatic with a manual override. The customer shall specify the sources of the control signal and its sensitivity and range, as well as the items to be furnished by the vendor.

12.7.2 For variable speed drive, the control signal shall act to reset the driver speed governing system. Unless specified otherwise, the control, range limits shall be from maximum continuous speed to 95 per cent of the minimum speed required for any operating range or 70 percent of the maximum continuous speed, whichever is lower.

12.7.3 For constant speed drive, the control system shall actuate either the control valve in the compressor inlet piping (furnished by the customer) or the adjustable inlet guide vanes furnished by the vendor as an integral part of the compressor. In the later case, the vendor shall also furnish a guide vane positioner compatible with the type of control signal specified by the customer and shall include a hand wheel and other means of local manual over-ride during operation. A direct-driven vane-position indicator shall be provided, which is visible during the operation of the machine.

12.7.4 A combination of control modes may be required on limited speed range drives and multi-service or multi-stream applications.

12.7.5 The full range of the customer's specified control limit shall correspond to the required operating range of the compressor. Unless specified otherwise, the maximum control signal shall correspond to the maximum continuous speed or the maximum flow position of the inlet control valves or adjustable inlet guide vanes.

12.8 Minimum Instrumentation

12.8.1 The customer shall specify the requirements of panel instruments.

12.8.2 Locally mounted instruments shall include temperature indicators and pressure gauges, before and after any intercoolers, supplied by the vendor provided the vendor supplies the interconnecting piping also.

12.8.3 The customer shall specify any additional instrumentation to be furnished by the vendor.

13 INSPECTION

13.1 If shop inspection is specified, the inspector representing the customer shall have entry to the plants, including the plants of the sub-vendors where work on or testing of the equipment is being performed.

13.2 It is intended that the customer inspection work may be minimized by assigning to the vendor, the responsibility of furnishing the inspector with all necessary material certificates, shop test reports, radiographic results, etc., which are necessary to verify the vendor's compliance with the specifications covering the compressor and all auxiliaries furnished by the vendor.

13.3 Wherever shop inspection is specified; no surfaces or parts shall be painted until the inspection is completed.

13.4 Whenever, during the manufacturing schedule, shop inspection by the customer is required, the vendor seal give sufficient advance notice to the customer. The period of advance notice can be established by mutual consent between the customer and the vendor.

13.5 Where shop inspection is required, it shall be the responsibility of the vendor to notify the sub-vendors of the customer's inspection requirements.

14 TESTS

14.1 General

14.1.1 All compressors shall be tested in accordance with **14.2** and **14.3**. Optional tests that may be specified shall be as described in **14.4**.

14.1.2 The customer shall reserve the right to witness testing, dismantling, inspection and reassembly of equipment as specified.

14.1.3 Acceptance of shop tests shall not constitute a waiver of requirements to meet the specified operating conditions, nor does inspection in any way relieves the vendor of his responsibilities.

14.2 Hydraulic Test

14.2.1 Parts shall be hydrostatically tested with liquid in accordance with the schedule:

Sl No.	*Item*	*Minimum Test Pressure*
(1)	(2)	(3)
i)	Complete casing including all-welded connections (unless agreed other-wise the customer)	1·5 times the maximum casing design pressure
ii)	Pressure vessels, process coolers and piping	1·5 times the maximum operating pressure or in accordance with applicable codes

14.2.2 The test set-up shall be maintained for a sufficient period to permit complete examination of the parts under pressure. The hydrostatic test shall be considered satisfactory when no leaks are observed for a minimum period of 30 min.

14.3 Mechanical Run Test

14.3.1 The following sequence shall be followed in conducting the mechanical run test for variable speed machines:

a) Start the compressor from a standstill and raise the speed up to maximum continuous speed, preferably in 10 percent speed increments. Allow the bearing to stabilize at the maximum continuous speed.

b) Increase the speed to 110 percent of maximum continuous speed and keep the compressor running for a minimum period of 15 min.

c) Bring down the speed to maximum continuous speed and keep the compressor running uninterrupted for four hours.

d) After four hours of the uninterrupted run at a maximum continuous speed, reduce the speed gradually to a standstill. For flexible shaft rotors, during this running down establish the actual first critical speed.

14.3.2 For fixed speed integrally geared compressors mechanical run test shall be conducted at rated operating speed for a continuous four-hour period.

14.3.3 Following the mechanical run test, carry out a static seal test in the case of compressors having oil seals. During this test, check the amount of inward oil leakage from each seal, with approximate design differential pressures established.

14.3.4 During the mechanical run test, the compressor shall operate satisfactorily. Vibration measurements shall be recorded throughout the operating speed range and shall not exceed the limits indicated in **9.18.4**. When the compressor is operating at a maximum continuous speed, a sweep shall be made for vibration amplitudes at frequencies other than synchronous (for running speed in rpm). As a minimum, the sweep shall cover a run of 0.25 synchronous to twice the vane passing frequency. If the amplitude of any discrete nonsynchronous vibration exceeds 10 percent of the allowable level as defined in **9.18.4**, the customer and the vendor shall mutually agree regarding additional testing, if any, and the suitability of the machine for shipment.

Preferably, contact vibration probes and detectors shall be used during the mechanical run test. If vibration probes are not furnished by the compressor vendor or if the contract probes are not compatible with the readout facilities available at the testbed, shop probes along with readout shall be used. Facilities at the testbed shall include instrumentation with the capability of the continuous X-Y presentation to measure and record frequency, peak-to-peak displacement and phase shift. The customer shall specify when these facilities shall be used for shop tests.

14.3.5 The actual first critical speed as established during the mechanical run test (in the case of flexible shaft compressors) shall be stamped on the nameplate.

14.3.6 If spare compressor rotors are ordered together with the compressors, each spare rotor shall also undergo at least a clearance check in the casing in accordance with the requirements.

14.3.7 All bearings and end seals (except labyrinth type seal) shall be removed after mechanical run test and inspected and reassembled.

14.3.8 If it becomes necessary to replace the bearings or seals or if dismantling the casing is required to improve mechanical operation the mechanical run test may be repeated after replacements and corrections are made.

14.3.9 The prototype model casings for toxic or combustible gas services shall be pressurized with an inert gas to the rated discharge pressure and held at this pressure for a minimum period of 30 min to check the gas leaks by subjecting to a soap bubble test. This shall be done after the mechanical run test.

14.3.10 The vendor shall maintain a complete log of all final tests and shall submit to the customer the required number of copies. These logs shall include data for

bearing and seal oil temperatures and pressures, seal oil leakage, pressurized gas test, rotors balancing, critical speeds and vibration measurements taken over the operating speed range and the non-synchronous sweep.

14.4 Optional Test

14.4.1 The customer shall specify if any of the following optional tests shall be performed on the compressor, gearbox, prime mover, and auxiliary equipment:

a) *Performance test* — The compressor shall be performance tested as agreed between the manufacturer and the purchaser.

b) *Complete unit test* — During this test such components as compressors, gearboxes, prime movers and auxiliaries that make up a complete compressor unit shall be tested together during the mechanical run test. If approved by the customer, the auxiliaries may be tested separately.

c) *Tandem test* — Compressor bodies arranged for tandem drive shall be tested as a unit during mechanical run test using the shop prime mover and oil system.

d) *Gear-box test* — The gearbox shall be tested with the compressor unit during the mechanical run test. During this test, the vendor shall subject the gearbox to partial load and demonstrate satisfactory performance.

e) *Noise level measurements* — The level of noise emanating from the compressor shall be measured during this test according to IS 4758.

f) *Post-test inspection* — Dismantling, inspection, and reassembly of the compressor, gearbox and the prime mover shall be made after satisfactory completion of the mechanical run test. The customer shall specify whether the pressurized gas test required according to **14.3.9** shall be performed before or after the post-test inspection.

15 NAME PLATE

The name plate and the arrow indicating the direction of rotation, to be fixed on the compressor, shall be out of 18/8 stainless steel or monel and shall be fixed by rivets. The following minimum data shall be stamped on the name plate:

a) Manufacturer’s name;

b) Serial number;

c) Size and Type;

d) Normal capacity;

e) First critical speed;

f) Maximum continuous speed;

g) Casing design pressure (*Max)*; and

h) Maximum allowable temperature.

16 PREPARATION FOR SHIPMENT

16.1 Each unit shall be prepared for shipment suitable for storage for a minimum period of six months, without requiring disassembly prior to operation. Following the final tests and post-test inspection, all exposed machined surfaces shall be coated thoroughly with a rust preventive. All exterior surfaces of the unit except machined surfaces shall be given a prime coat of paint in the shop. The interior of the compressor and all bearing housings shall be either sprayed or flushed with a suitable rust preventive which can be later removed by flushing a solvent. This shall be done through all inlets with the machine kept slowly rotating.

16.2 All flanged openings shall be provided with metal closures of 4 mm minimum thickness, together with rubber gaskets and at least four full-sized bolts. All unpiped threaded openings shall be fitted with solid shank steel plugs or caps.

16.3 The compressor shall be packed securely for the shipment specified (domestic or export). Lifting points or lugs shall be clearly marked. Each compressor shall be properly identified with the item and serial numbers. Materials shipped separately shall be properly identified with securely affixed corrosive-resistant metal tags, indicating the items and serial numbers for which it is intended.

16.4 If the storage is for periods exceeding six months, the customer shall consult the vendor regarding re-preservation.

16.5 If the spare rotor is specified, it shall be suitably prepared for storage in unheated indoors. The rotor shall be treated with a rust preventive and shall be housed in a vapour barrier envelope. The rotor shall be suitably created for domestic or export shipment as specified. At the support areas, suitable lead sheeting shall be used between the rotor and the cradle. During storage, the rotor shall be turned periodically as per the vendor’s recommendations to prevent a permanent sag setting in the shaft.

16.6 All components shipped with mounted, preassembled piping, tubing’s and wiring shall comply with the relevant safety requirements and shall carry on an all-weather tag stating in bold letters as follow:

‘This System Has Been Preassembled And Tested For Operatibility And Safety And Complies With Relevant Safety Requirements And Shall Not Be Disturbed By Unauthorized Personnel.”

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS/ISO No.	*Title*
554 : 1999	Pipe threads where pressure-tight joints are made on the threads — Dimensions, tolerances and designation (*fourth revision*)
817 : 1966	Code of practice for training and testing of metal arc welders
1239 (Part 2) : 2011	Steel tubes, tubulars and other steel fittings — Specification: Part 2 Steel pipe fittings (*fifth revision*)
1536 : 2001	Centrifugally cast (Spun) iron pressure pipes for water, gas and sewage — Specification (*fourth revision*)
1537 : 1976	Specification for vertically cast iron pressure pipes for water, gas and sewage (*first revision*)
1570 (Part 1) : 1978	Schedules for wrought steels: Part 1 Steels specified by tensile and/or yield properties (*first revision*)
1570 (Part 5) : 1985	Schedules for wrought steels: Part 5 Stainless and heat — Resisting steels (*second revision*)
2644 : 1994	High strength steel castings for general engineering and structural purposes — Specification (*fourth revision*)
2825 : 1969	Code for unfired pressure vessels
3681 : 1995	Gears — Cylindrical, gears — Accuracies (*first revision*)
4218 (Part 1) : 2001	ISO general purpose metric screw threads: Part 1 Basic profile (*second revision*)
4218 (Part 2) : 2001	ISO general purpose metric screw threads: Part 2 General plan (*second revision*)
4218 (Part 3) : 1999	ISO general purpose metric screw threads: Part 3 Basic dimensions (*second revision*)
4218 (Part 4) : 2001	ISO general purpose metric screw threads : Part 4 selected sizes for screws, bolts and nuts (*second revision*)
14962 (Part 2) : 2001	ISO general purpose metric screw threads — Tolerances: Part 2 Limits of sizes for general purpose external and internal screw threads — medium quality
4864 : 1968 to 4870 : 1968	Specification for shell flanges for vessels and equipment
4758 : 1968	Methods of measurement of noise emitted by machines
5334 : 2014	Magnetic particle flaw detection of welds — Code of practice (*third revision*)
6916 : 1973	Code of practice for fabrication welding of steel castings
8593 (Part 1) : 2017	Recommendations for centralised lubrication as applied to plant and machinery: Part 1 Oil lubrication (*first revision*)
IS/ISO 21940-11 : 2016	Mechanical vibration — Rotor balancing: Part 11 Procedures and tolerances for rotors with rigid behavior
IS/IEC 60034-5 : 2000	Rotating electrical machines: Part 5 Degrees of protection provided by the integral design of rotating electrical machines (IP Code) — Classification (*second revision*)

ANNEX B

(*Clause* 3)

TECHNICAL DATA TO BE FURNISHED ALONG WITH CUSTOMER'S ENQUIRY

CUSTOMER:	PLANT:
SITE:	SERVICE:
ITEM REQUIRED:	NO. OFF:

B-1 SITE CONDITIONS

B-1.1 Altitude (metres above MSL) _____

B-1.2 Temperature during:

a) Winter (*Min*)
b) Summer (*Max*)

B-1.3 Relative humidity (percent)

B-1.4 Barometric pressure (bar)

B-1.5 Area classification (hazardous/non-hazardous)

B-1.6 installation:

a) Indoor (heated/non-heated)
b) Outdoor (open/under roof)

B-1.7 Protection (winterization/tropicalization)

B-2 GAS CHARACTERISTICS

B-2.1 Gas handled

B-2.2 Composition by volume (percent)

B-2.3 Particle/dust concentration (if any)

B-2.4 Molecular weight (mole)

B-2.5 Specific heat ratio (C_p/C_v)

B-2.6 Compressibility factor (Z)

a) At suction
b) At discharge

B-2.7 Fouling factor-gas side

B-3 PROCESS DETAILS

B-3.1 Suction pressure (bar)

B-3.2 Suction temperature (°C)

B-3.3 Discharge pressure (bar)

B-3.4 Discharge temperature limited to (°C)

B-3.5 Capacity (Nm^3/h):

a) Normal
b) Maximum

B-3.6 Side streams, if any:

a) Capacity (Nm^3/h)
b) Pressure (bar)
c) Temperature (°C)
d) Composition by Volume (percent)

B-4 PRIME MOVER

B-4.1 Type (steam turbine, electric motor, gas turbine)

B-4.2 Steam parameters (for steam turbine drives)

		Normal	*Maximum*	*Minimum*
a)	Inlet pressure (bar)			
b)	Inlet temperature (°C)			
c)	Extraction pressure (bar)			
d)	Extraction temperature (°C)			
e)	Exhaust pressure (bar)			
f)	Exhaust temperature (°C)			
g)	Extraction quantity (kg/h)			

B-4.3

a) Fuel composition (percent by Volume) (for gas turbine drives)
b) Calorific value (kcal)

B-4.4 Atmospheric air characteristics:

a) Dust concentration (in ppm)
b) Corrosive constituents

B-4.5 Fuel supply parameters

B-4.6 System conditions (for electric motor drives):

a) Rated voltage (kV)
b) No. of phases (single/three)
c) Frequency (Hz)
d) Service factor
e) Voltage dip (percent)
f) Starting (full load/No-load, full voltage/reduced voltage, etc)

B-5 UTILITIES FOR AUXILIARIES

B-5.1 Electric power:

a) Voltage (V);
b) No. of phases (single/three); and
c) Frequency (Hz).

B-5.2 Steam:

		Normal	*Maximum*	*Minimum*
a)	Inlet pressure (bar)			
b)	Inlet temperature (°C)			
c)	Back pressure (bar)			

B-5.3 Cooling water:

a) Pressure at supply limit (bar);
b) The temperature at supply limit (°C);
c) Temperature rise permitted;
d) Fouling factor (water side); and
e) Quality (fresh/river/sea).

B-5.4 DC power for trip circuits (220/440V).

B-5.5 Instrument air pressure (bar).

B-6 ADDITIONAL REMARKS, IF ANY

ANNEX C

(*Clause* 10.1.1)

MATERIALS FOR MAJOR COMPONENT PARTS

Sl No.	Part	Material Specified	Form	Temp Limits	
				Min °C	*Max* °C
1	Casing a) Cast and horizontally split	IS 210: 2009 (Gr FG 300) 'Grey iron castings (*fifth revision*)'or IS 3038 : 1983 Alloy steel castings for pressure containing parts suitable for high-temperature service (*first revision*) or IS 7806 : 1975 (Gr I) Ferritic and austenitic steel casings for high-temperature service or IS 3444 : 1978 Corrosion resistant alloy steel and nickel-based castings for general applications (*first revision*)	Cast Cast Cast Cast	–30 –30 –20 –100	260 400 340 340
	b) Fabricated and horizontally split	IS 2002 : 1982 Steel plates for boilers and IS 2041 : 1982 Steel plates for pressure vessels	Plate	10	340
	c) Vertically split barrel compressors	IS 2002 : 1982 Steel for boilers or IS 2041 : 1982 Steel plates for pressure vessels or IS 2004 : 1978 Carbon steel forgings for general engineering purposes (*second revision*) or IS 3038 : 1974 Alloy steel castings for pressure containing parts suitable for high-temperature service (*first revision*) or IS 3444 : 1978 Corrosion resistant alloy steel and nickel-based castings for general applications (*first revision*).	Plate Forged Cast Cast	10 –30 –30 –180	340 340 400 300
2	Diaphragm and guide vanes	IS 210 : 2009 (Gr FG 200) Grey iron castings (*fifth revision*) or IS 1865 : 1974 Iron castings with spheroidal or nodular graphite (*second revision*) or IS 3038 : 1974 Alloy steel castings for pressure containing parts suitable for high-temperature service (*first revision*) IS 2002 : 1982 Steel plates for boilers or IS 2041 : 1982 Steel plates for pressure vessels	Cast Cast Cast Plate	–195 –195 –195 –10	340 340 340 340

Sl No.	Part	Material Specified	Form	Temp Limits	
				Min °C	*Max* °C
3	Shaft	IS 1875 : 1992 Carbon steel billets, blooms, slabs and bars for forgings — Specification (*fifth revision*) or IS 3445 : 1992 Forged steel rolls — Specification (*first revision*) or IS 4367 : 1991 Alloy steel forgings for general industrial use — Specification (*first revision*) or IS 4368 : 1967 Alloy steel billets, blooms and slabs for forgings for general engineering purposes or IS 5517 : 1993 Steels for hardening and tempering — Specification (*second revision*)	Forged Forged	–30 –115	340 425
4	Impeller	IS 4367 : 1991 Alloy steel forgings for general industrial use — Specification (*first revision*) IS 6603 : 2001 Stainless steel bars and flats — Specification (*first revision*)	Forged Forged	–70 –30	340 340
5	Impeller discs and covers	IS 1875 : 1992 Carbon steel billets, blooms, slabs and bars for forgings — Specification (*fifth revision*) or IS 3445 : 1992 Forged steel rolls — Specification (*first revision*) or IS 4367 : 1991 Alloy steel forgings for general industrial use — Specification (*first revision*)	Forged Forged Forged	–30 –115 –70	440 400 340
6	Impeller vane	IS 4367 : 1991 Alloy steel forgings for general industrial use — Specification (*first revision*) IS 6603 : 2001 Stainless steel bars and flats — Specification (*first revision*)	Plate Forged/ rolled	–30 –70	340 340
7	Labyrinths	IS 617 : 1994 Cast aluminum and its alloys — Ingots and castings for general engineering purposes — Specification (*third revision*)	Cast	–195	315

Sl No.	Part	Material Specified	Form	Temp Limits	
				Min °C	*Max* °C
8	Balance	IS 1875 : 1992 Carbon steel billets, blooms, slabs and bars for forgings — Specification (*fifth revision*) or IS 3445 : 1992 Forged steel rolls — Specification (*first revision*) or IS 4368 : 1967 Alloy steel billets, blooms and slabs for forgings for general engineering purposes or IS 5517 : 1993 Steels for hardening and tempering — Specification (*second revision*) or IS 6603 : 2001 Stainless steel bars and flats — Specification (*first revision*)	Forged Forged Forged	–30 –115 –30	400 400 340
9	Shaft sleeves and labyrinth seas sleeves	IS 3445 : 1992 Forged steel rolls — Specification (*first revision*) or IS 4367 : 1991 Alloy steel forgings for general industrial use — Specification (*first revision*) or IS 4368 : 1967 Alloy steel billets, blooms and slabs for forgings for general engineering purposes or IS 5517 : 1993 Steels for hardening and tempering — Specification (*second revision*) or IS 6603 : 2001 Stainless steel bars and flats — Specification (*first revision*)	Forged Forged	–115 –30	400 340

ANNEX D

(*Foreword*)

COMMITTEE COMPOSITION

Compressor, Blowers and Exhausters Sectional Committee, MED 22

Organization	*Represntative(s)*
Bharat Petroleum Corporation Limited, Mumbai	Shri K. Ravi (***Chairman***)
A B B India Limited, Bengaluru	Shri N. S. Prasad
Atlas Copco India Limited, Pune	Shri Vijay Sharma
Bharat Heavy Electrical Limited, New Delhi	Shri V. P. Shyamsundar Shri Y. V. Rama Lakshmi (*Alternate*)
Boldrocchi Indian Private Limited, Gurugram	Shri Nokesh Aggarwal Shri Piyush Goel (*Alternate*)
Burckhardt Compression India Private Limited, Noida	Shri R. S. Gunaji Shri A. Bhaskar Prabhune (*Alternate*)
CSIR-National Physical Laboratory, New Delhi	Dr Rajesh Kumar Prof Dr M. Singh (*Alternate*)
Directorate General of Quality Assurance, Ministry of Defense, New Delhi	Lt Col Deepak Sharma Shri U. R. Raja (*Alternate*)
Dresser-Rand India Private Limited, Pune	Shri M. H. Vyas Shri J. B. Raval (*Alternate*)
ELGI Equipments Limited, Coimbatore	Shri Jayaraj B. Shri Jeyaselvan M. (*Alternate*)
Engineers India Limited, Gurugram	Shri J. S. Duggal Shri Mahesh Easwaran (*Alternate*)
Gail (India) Limited, New Delhi	Shri Satish Geda
Hindustan Petroleum Corporation Limited, Mumbai	Shri M. Rambabu Shri P. Venkatanarayana (*Alternate*)
Indian Oil Corporation Limited, New Delhi	Shri P. K. Jain
Indian Register of Shipping, Mumbai	Shri Pradeep Bansal Shri Atul Mani Sharma (*Alternate*)
Ingersoll Rand India Limited, Ahmedabad	Shri Ramesh K. V. Shri Dileep Patil (*Alternate*)
Kirloskar Pneumatic Company Limited, Pune	Shri Neeraj Bhargava Shri Avdhoot Bhide (*Alternate*)
MECON Limited, Ranchi	Shri A. K. Modi (*Alternate*)
NTPC Limited, New Delhi	Shri S. K. Jha
National Fertilizers Limited, Noida	Shri S. K. Sharma Shri Raman Gambhir (*Alternate*)
Neuman and Esser Compressor Application Centre Private Limited, Pune	Shri Kumar Puduru Shri Mahesh Dixit (*Alternate*)
Oil and Natural Gas Corporation Limited, New Delhi	Shri Braj Kishor Rai Shri Ritujit Hazarika (*Alternate*)
Project and Development India Limited, Noida	Shri S. Mandilwar Shri Ajay K. S. Ruhel (*Alternate*)

Organization	*Represntative(s)*
Reliance India Limited, Mumbai	Shri S. K. Garyali Shri Ranjit S. Mundra (*Alternate*)
Research Designs and Standards Organization (RDSO), Lucknow	Shri S. P. Govil
TLT Engineering India Private Limited, Gujrat	Shri Mukesh K. Jain Shri Sanjay Makwana (*Alternate*)
Tata Chemicals Limited, Mumbai	Shri M. S. Prasad Shri Ajoy Kumar Singh (*Alternate*)
Tata Consulting Engineers Limited, Navi Mumbai	Shri Shireesh S. Swami Shri Aslam Basha B. (*Alternate*)
BIS Directorate General	Shri Rajneesh Khosla, Scientist 'E' and Head (MED) [Representing Director General (*Ex-officio*)]

Member Secretary

Shri Lokraj Meena
Scientist 'B' (MED), BIS

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